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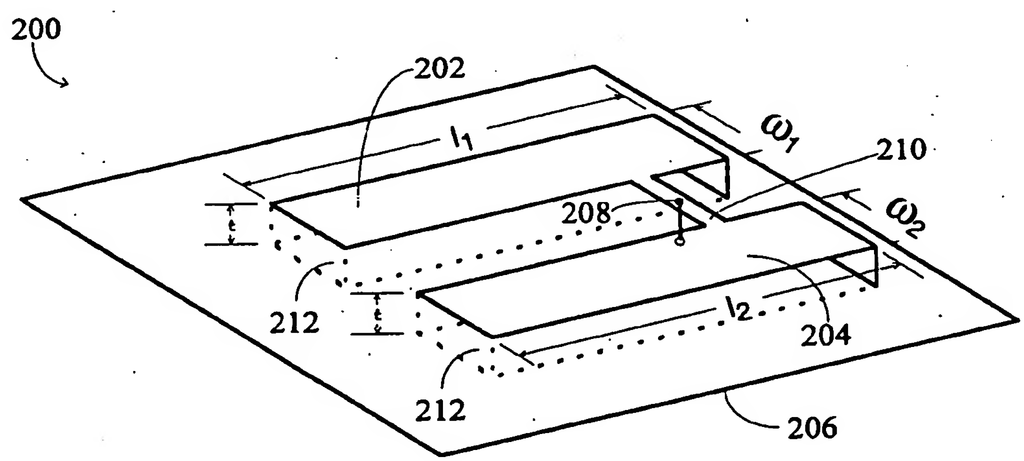

(57) Abstract

A dual-frequency-band patch antenna (200) capable of resonating at two different operating frequencies. The dual-frequency-band patch antenna (200) includes two conductive plates (202, 204) that are placed side by side, with one conductive plate sized to resonate at a first frequency and the other conductive plate sized to resonate at a second frequency. The conductive plates (202, 204) are electrically joined by an electrical connection (210), and share a single feed (208) from a transceiver. The conductive plates (202, 204) are separated from a ground plane (206) by a dielectric medium (212), which according to the present invention is very thin in terms of the wavelength at which the antenna operates (*i.e.*, "low-profile"). When the antenna is excited at the first frequency, the first conductive plate (202) resonates like a conventional patch antenna. The second conductive plate (204), however, acts like a parasitic patch, thereby increasing the overall bandwidth and efficiency. Conversely, when the antenna (200) is excited at the second frequency, the second conductive plate (204) resonates and the first conductive plates (202) acts like a parasitic patch.

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DUAL-FREQUENCY-BAND PATCH ANTENNA WITH ALTERNATING ACTIVE AND PASSIVE ELEMENTS

BACKGROUND OF THE INVENTION

I. Field of the Invention

The present invention relates to patch antennas. More particularly, the present invention relates to a novel and improved patch antenna which provides a low-profile design, dual-frequency-band operation, and increased bandwidth and efficiency compared to conventional patch antennas.

II. Description of the Related Art

Patch antennas were originally developed in the late 1960's and early 1970's for use with high-velocity aircraft, missiles, and other military applications requiring a "paper thin," or low-profile, antenna. These systems required that the antenna neither disturb the aerodynamic flow, nor protrude inwardly to disrupt the mechanical structure. The patch, or microstrip, antenna satisfied these requirements. These antennas were also cheap and easy to manufacture using well-developed printed circuit board technology.

Today, many applications require low cost, low-profile antennas. For example, patch antennas might be used in conjunction with personal communication devices (*e.g.*, cellular hand-held phones, mobile phones) and portable GPS systems. New generations of military and civilian aircraft continue to require ever smaller and higher-performance devices as well.

Some applications require that the patch antenna operate (*i.e.*, transmit or receive) at multiple frequencies. However, patch antennas are inherently narrowband devices. Generally speaking, bandwidth is proportional to the volume of the antenna. Because patch antennas are commonly developed for low-profile applications, their volume is purposefully minimized. It is, therefore, difficult to broaden the bandwidth of a conventional patch antenna sufficiently to encompass the frequencies of interest, without unacceptably increasing the antenna's profile.

One approach for providing multi-frequency-band operation is to have multiple antenna elements, one element designed to resonate at each frequency of interest. This approach does provide multi-band operation. However, this system is far more complex and costly when compared to a conventional, single element patch antenna. This approach requires a power divider network for splitting the driving signal amongst the antenna elements, and some means for switching between them.

Another approach is to broaden the bandwidth of a patch antenna by adding "parasitic" elements. Parasitic elements are antenna elements that are not electrically connected to a transmitter or receiver. Rather, currents are induced in these elements by the fields of a driven element. Parasitic elements effectively increase the volume of the driven element, thereby increasing the antenna's overall bandwidth and efficiency. However, in many instances the increased bandwidth will still fall short of that required to encompass the various operating frequencies within a communication system.

Thus, there exists a need for a low-profile, simple, low-cost patch antenna capable of operating in multiple frequency bands.

SUMMARY OF THE INVENTION

The present invention is a novel and improved low-profile, dual-frequency-band patch antenna having two conductive plates electrically connected, and separated from a ground plane by a very thin dielectric medium. According to the invention, each conductive plate is designed to operate at one of the frequencies of interest.

An advantage provided by the current invention is improved performance at each frequency of interest as compared to a conventional patch antenna. When the antenna operates at a first frequency, the first conductive plate radiates while the second acts as a parasitic patch, thereby increasing the effective bandwidth and efficiency. Similarly, when the antenna operates at a second frequency, the second conductive patch radiates while the first acts as a parasitic patch. The present invention may simply switch between these two modes of operation, as required by the particular application.

The present invention radiates with a nearly omnidirectional beam pattern. This characteristic is desirable in many applications to which the patch antenna is particularly well suited.

The present invention provides this dual-band operation at low cost and minimal design complexity. Both conductive plates share a single connection to the antenna's signal unit. The present invention is, therefore, able to achieve dual-frequency-band operation without requiring a means for switching the signal unit between multiple connections.

BRIEF DESCRIPTION OF THE DRAWINGS

The features, objects, and advantages of the present invention will become more apparent from the detailed description set forth below when taken in conjunction with the drawings in which like reference numbers indicate identical or functionally similar elements. Additionally, the left-most digit of a reference number identifies the drawing in which the reference number first appears, and:

FIG. 1A is a diagram illustrating a conventional patch antenna from a three-dimensional perspective;

FIG. 1B is a diagram illustrating a conventional patch antenna from a cross-sectional view;

FIG. 2 is a diagram illustrating a dual-band patch antenna with both active and passive elements;

FIG. 3 is a diagram illustrating the dual-band patch antenna as configured for an example application;

FIG. 4 is a graph illustrating the frequency response of the dual-band patch antenna as shown in FIG. 3;

FIGS. 5A and 5B are graphs illustrating the beam pattern, at a first frequency, of the dual-band patch antenna as shown in FIG. 3, where FIG. 5A is for phi = 0 degrees and FIG. 5B is for phi = 90 degrees;

FIGS. 6A and 6B are graphs illustrating the beam pattern, at a second frequency, of the dual-band patch antenna as shown in FIG. 3 where FIG. 6A is for phi = 0 degrees and FIG. 6B is for phi = 90 degrees.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

I. Overview and Discussion of the Invention

The present invention is directed toward a dual-frequency-band patch antenna capable of resonating at two different operating frequencies. According to the invention, two conductive plates are placed side by side, with one conductive plate sized to resonate at a first frequency and the other conductive plate sized to resonate at a second frequency. The conductive plates are electrically joined by an electrical connection, and share a single feed from a signal unit.

The conductive plates are separated from a ground plane by a dielectric medium, which according to the present invention is very thin in

terms of the wavelength at which the antenna operates (*i.e.*, "low-profile"). When the antenna is excited at the first frequency, the first conductive plate resonates like a conventional patch antenna. The second conductive plate, however, acts like a parasitic patch, thereby increasing the antenna's overall bandwidth and efficiency. Conversely, when the antenna is excited at the second frequency, the second conductive plate resonates and the first acts like a parasitic patch. The manner in which this is accomplished is described in detail below.

Note that the term "signal unit" is used herein to refer generally to the functionality provided by a radio frequency (RF) signal source and/or an RF signal receiver. Whether the signal unit provides one or both of these functionalities depends upon how the antenna is configured to operate. The antenna could, for example, be configured to operate solely as a transmission element or radiator, in which case the signal unit generally operates as an RF signal source. Alternatively, the signal unit operates as an RF signal receiver when the antenna is configured to operate solely as a reception element (radiator). The signal unit provides both functionalities (*e.g.*, a transceiver) when the antenna is configured to operate as both a transmission and reception element. In the last example, the source and receiver functionalities might be implemented as the same or separate physical components. Those skilled in the art will recognize the various ways in which the functionality of generating and/or receiving RF signals might be implemented.

II. Conventional Patch Antennas

Before describing the invention in detail, it is useful to first describe conventional patch antennas. FIG. **1** is a diagram illustrating a conventional patch antenna **100** from a three-dimensional perspective (FIG. **1A**) and a cross-sectional view **110** (FIG. **1B**). A conductive plate **102** (*i.e.*, the "patch") is separated from a ground plane **104** by a dielectric medium **106** of a given thickness *t* Note that conductive plate **102** connects to the ground plane on one end, forming an "L-shape" in cross-section. One skilled in the art will recognize that this "L-shaped" connection might be alternatively implemented in a number of different ways, provided an electrical connection between the end of the conductive plate and the ground plane is made.

As shown in FIG. **1A**, conductive plate **102** is a thin piece of conductive material, such as aluminum, copper, brass, silver, gold, or other

metal, with a length ℓ and a width w. The length ℓ is set in relation to the wavelength λ_0 associated with the desired resonant frequency f_0. Commonly used lengths are $\ell = \lambda$, $^1/_2\lambda$, and $^1/_4\lambda$. The width w must be less than a wavelength so that higher-order modes will not be excited.

As shown in FIG. 1B, a feed **108** is connected to conductive plate **102**, passing through dielectric medium **106** and ground plane **104**. Feed **108** provides the electrical connection between conductive plate **102** and a signal unit **110**. As would be clear to one skilled in the art, feed **108** may be alternatively implemented in a number of different ways (*e.g.*, a probe connector).

As a transmission device, signal unit **110** provides a pre-selected RF signal at resonant frequency f_0 causing conductive plate **102** to resonate and thereby radiate electromagnetic waves. As a receiving device, patch antenna **100** receives an electromagnetic wave propagating through space and converts the wave to a guided wave which is transferred to signal unit **110** via feed **108**.

Patch antennas are often used for low-profile applications because the thickness t is usually much less than a wavelength. Dielectric medium **106**, which occupies the space between conductive plate **102** and ground plane **104** with a thickness t might be air ($\varepsilon_r = 1$), or another material with a higher relative permativity ($\varepsilon_r > 1$).

Several parameters are generally used to measure the performance of patch antennas. Radiation patterns measure the amount of power radiated by the antenna in each direction. The particular application for which the antenna is being used determines whether it is desirable to focus the antenna's radiation in a particular direction, or whether an omnidirectional pattern (antenna radiates in all directions equally) is preferable. For example, the conventional patch antenna **100** with a length $\ell = {}^1/_4\lambda_0$ ("quarter-wavelength" patch antenna) radiates omni-directionally, given an infinite ground plane.

Antenna bandwidth refers to a range of frequency over which the antenna may effectively operate (*i.e.*, transmit or receive). The bandwidth of patch antennas is proportional to the antenna's volume. Thus, bandwidth is increased by increasing either the length ℓ or width w of conductive plate **102**, or the thickness t of the antenna, as shown in FIG. 1. Since most applications require that the antenna operate at specified frequencies, the length and width are largely set and cannot be adjusted. Similarly, patch antennas are often used in applications requiring a low-profile, which limits

the extent to which t may be increased to increase bandwidth. Thus, due to these constraints, bandwidths for patch antennas are often narrow.

Patch antenna efficiency is defined as the power radiated divided by the power received by the input to the antenna. Efficiency is reduced by several factors including dielectric loss, the conductor loss, the reflected power, the cross-polarized loss, and any load loss. For very thin elements the current losses increase and the conductance across the cavity yields excessive dielectric losses. Note that dielectric losses are eliminated by using air as a dielectric medium.

III. Dual-frequency-band Patch Antenna with Alternating Active and Passive Elements

Many applications today require a low-profile antenna that is able to operate at two arbitrarily chosen frequencies (*e.g.*, frequencies that are not harmonically related). The conventional patch antenna as shown in FIG. 1 and described above often cannot satisfy both of these requirements, as they are inversely related according to antenna thickness t increasing t broadens the bandwidth of the antenna, possibly wide enough to encompass both frequencies, but also increases the profile of the antenna.

FIG. 2 is a diagram illustrating a dual-band patch antenna **200**. A first conductive plate **202** and a second conductive plate **204** are separated from a ground plane **206** by a dielectric medium **212** of thickness t. In a preferred embodiment, the thickness t of dielectric medium **212** is constant between both conductive plates and ground plane **206**. Restricting the design to a constant thickness simplifies fabrication of the antenna. However, one skilled in the art will recognize that other embodiments are possible. For example, certain applications might benefit from a thickness t_1 of the dielectric medium under first conductor plate **202**, and thickness t_2 under second conductor plate **204**. Such an embodiment might increase performance of the antenna in terms of efficiency and bandwidth (see below) for particular applications, possibly justifying the additional costs in fabrication.

Note that both conductive plates **202** and **204** connect to the ground plane on one end, forming an "L-shape" in cross-section. One skilled in the art will recognize that this "L-shaped" connection might be alternatively implemented in a number of different ways, provided an electrical connection between the end of the conductive plate and the ground plane is made.

An electrical connection **210** electrically connects the first and second conductive plates. A feed **208** is connected to electrical connection **210**, passing through dielectric medium **212** and ground plane **206**. One skilled in the art will recognize that electrical connection **210** as shown in FIG. 2 might also be implemented in a number of different ways. The salient point is that the two conductive plates are electrically connected, and that they share a single feed **208**.

As discussed with respect to the conventional patch antenna, the geometries of the conductive plates depend significantly on the particular resonant frequency (and corresponding wavelength λ_0) at which the conductive plate is to operate. According to the present invention, the first and second conductive plates are sized according to different resonant frequencies. These two resonant frequencies are set equal to the two frequencies required for dual-frequency-band operation.

In a preferred embodiment, the length ℓ_1 of first conductive plate **202** is equal to $\lambda_1/4$, corresponding to a first frequency f_1. The length ℓ_2 of second conductive plate **204** is equal to $\lambda_2/4$, corresponding to a second frequency f_2. Again, the widths w_1 and w_2 must be less than a wavelength (λ_1 or λ_2, respectively) so that higher-order modes will not be excited.

As with the conventional patch antenna, feed **208** provides the electrical connection between the conductive plates and signal unit **110**, as shown in FIG. **1** (not reproduced in FIG. **2**). Signal unit **110** now operates alternately at RF frequencies f_1 and f_2.

The current invention has two normal modes of operation. The following discussion describes each mode with respect to signal transmission. However, one skilled in the art will recognize that the principles discussed below apply equally well to signal reception.

In a first mode, signal unit **110** provides an RF signal at first frequency f_1 Most of the current flows through feed **208** and into first conductive plate **202** sized to the first frequency f_1 First conductive plate **202** resonates at f_1 thereby radiating electromagnetic waves. The radiating element is referred to as the "active" element.

Second conductive plate **204**, the "passive" element, draws only a negligible amount of current. Current enters dual-band patch antenna **200** at feed **208**, and may either flow into the active or passive element. However, the passive element may be approximated by an open circuit because the effective impedance of the passive element as seen from feed **208** is much higher than the impedance of the active element (approximately 50 ohms).

This high impedance is a function of two characteristics. First, the antenna is very thin (*i.e.*, thickness *t* is very small in terms of wavelength) which increases the impedance of both elements. Second, the geometry of the active element is sized to resonate at the input frequency, whereas the geometry of the passive element is not. As a result of these two characteristics, the passive element has a much higher impedance relative to the active element, causing most of the current to flow into the active element.

The passive element effectively acts like a parasitic patch. As discussed above, a conventional parasitic element would not be electrically connected to signal unit **110**. The passive element in the current invention approximates this condition because the element draws so little current that it might be considered unconnected to signal unit **110**. As with a parasitic patch, currents are induced in the passive element by the fields of the active element.

Dual-band patch antenna **200** realizes improved performance as a result of the passive element acting like a parasitic patch. The passive element increases the effective volume of the antenna, which in turn increases both the bandwidth and the efficiency of the antenna.

One skilled in the art will readily recognize the design tradeoffs inherent in this situation. Dual-band patch antenna **200** might be designed with bandwidth and efficiency comparable to conventional patch antennas, but with a lower profile. The lower profile is possible because of the additional volume contributed by the passive element. Alternatively, the antenna's profile might be held constant in order to achieve increased efficiency and bandwidth. Numerous other permutations might be achieved to satisfy the requirements of a particular application, as would be clear to one skilled in the art.

In a second normal mode of operation, signal unit **110** provides an RF signal at second frequency f_2. Most of the current now flows through feed **208** and into second conductive plate **204** sized to the second frequency f_2 Second conductive plate **204** resonates at f_2 thereby radiating electromagnetic waves. Here, second conductive plate **204** is the active element, and first conductive plate **202** is the passive element. Dual-band patch antenna **200** operates as described above with respect to the first mode, except that the roles of the two conductive plates have been reversed and the antenna radiates at f_2.

Thus, the current invention provides dual-band operation with improved bandwidth and efficiency over conventional designs, combined

with a very low-profile design. The design is also greatly simplified in comparison to conventional designs as a result of requiring only a single feed. Approaches which require a separate feed for each element also require a switching network for alternately connecting the signal unit **110** to each of the feeds. These additional requirements greatly increase system cost and complexity. By sharing a single feed, the current invention avoids this additional cost and complexity.

One skilled in the art will readily recognize that the above described concepts might be implemented in a number of alternative embodiments. For instance, the geometries of the conductive plates might be adjusted to accommodate a specific application. Alternatively, the geometry of the ground plane might be adjusted as required.

One skilled in the art will also recognize that the above described antenna may be implemented using a variety of materials and methods of fabrication. The antenna as implemented may be flexible or rigid, as appropriate for the desired application. Further, the antenna may be constructed to conform to a variety of non-planar or arcuate surfaces to which the antenna will be attached. For example, the antenna may be shaped to conform to a curved surface of a cellular telephone housing.

In another alternative embodiment, additional elements might be connected alongside the first two to achieve multi-band operation. This embodiment is a direct extension of the above described principles. Any number of conductive plates might be added, each sized according to a different frequency of interest. The conductive plates would all share a common feed, as described above. Most of the current would flow into the active element. All the other passive elements would draw negligible current and thus act as parasitic patches, further increasing efficiency and bandwidth.

IV. Example Environment

In a broad sense, the current invention can be implemented in any system for which patch antenna technology can be utilized, particularly those requiring a low-profile, dual-frequency-band antenna. One example of such an environment is a tracking system whereby a low-profile patch antenna is mounted on a tractor trailer to provide geo-location data in the event the trailer is stolen. In this example environment, the antenna must communicate with one or more satellites at two different frequencies, one for transmitting and one for receiving.

FIG. 3 is a diagram illustrating the example dual-band patch antenna 300. A first conductive plate 302 and a second conductive plate 304 are separated from a ground plane 306 by a dielectric medium 312 of thickness *t*. In this example embodiment, air is the chosen dielectric medium. As depicted in FIG. 3, exact geometries are provided for the conductive plates, dielectric medium 312, and ground plane 306.

The example application requires a very low-profile antenna. Tractor trailers must meet strict specifications with respect to the height of the trailer. Since the antenna is generally mounted on the roof of the trailer, the antenna's profile is of central importance. The thickness of example dual-band patch antenna 300 is given as 0.75 inches. Given the wavelength at which the antenna operates, this is a lower profile than would be possible using a conventional design.

Dual-band patch antenna 300 is designed to operate at approximately 135-155 MHz. FIG. 4 is a graph 400 depicting the frequency response of antenna 300 with the specific geometry shown in FIG. 3. Low frequency 402 (approximately 141 MHz) operates as the receiving band. Dual-band antenna 300 receives signals from a satellite at this frequency. High frequency 404 (approximately 151 MHz) operates as the transmitting band for transmitting signals to a satellite.

FIG. 5A is a graph 500 depicting the beam pattern of the example antenna 300 at low frequency 402 and phi = 0 degrees. FIG. 5B is a graph 502 depicting the beam pattern at low frequency 402 and phi = 90 degrees. Similarly, FIG. 6A is a graph 600 depicting the beam pattern at high frequency 404 and phi = 0 degrees, and FIG. 6B is a graph 602 depicting the beam pattern at high frequency 404 and phi = 90 degrees.

As can be seen, antenna 300 radiates in a substantially omnidirectional pattern at both frequencies. The example application requires that the antenna have such a characteristic beam pattern. When receiving, the desired signal might impinge upon the antenna from any direction with equal probability. Similarly, when transmitting, the target satellite might lay in any direction. In such a situation, optimum performance is achieved by radiating or receiving in all directions uniformly.

V. Conclusion

While various embodiments of the present invention have been described above, it should be understood that they have been presented by

way of example only, and not limitation. Thus, the breadth and scope of the present invention should not be limited by any of the above-described exemplary embodiments, but should be defined only in accordance with the following claims and their equivalents.

The previous description of the preferred embodiments is provided to enable any person skilled in the art to make or use the present invention. While the invention has been particularly shown and described with reference to preferred embodiments thereof, it will be understood by those skilled in the art that various changes in form and details may be made therein without departing from the spirit and scope of the invention.

What I claim as the invention is:

CLAIMS

1. A dual-frequency-band patch antenna, comprising:

a first conductive plate sized to resonate at a first frequency;

a second conductive plate sized to resonate at a second frequency different from said first frequency;

an electrical connection electrically connecting said first conductive plate to said second conductive plate; and

a ground plane separated from said first and second conductive plates by a dielectric medium of a certain thickness, said ground plane electrically connected to said first and second conductive plates, and wherein said thickness is sufficiently small such that when said first conductive plate resonates at said first frequency said second conductive plate draws a negligible current, and such that when said second conductive plate resonates at said second frequency said first conductive plate draws a negligible current.

2. The antenna according to claim 1, wherein said first and second conductive plates transmit energy with a substantially omnidirectional beam pattern.

3. The antenna according to claim 1, further comprising:

a feed connected to said electrical connection; and

a signal unit connected to said feed.

4. The antenna according to claim 3, wherein said signal unit comprises an RF signal source, an RF signal receiver, or an RF transceiver.

5. The antenna according to claim 1, wherein said dielectric medium is air.

6. The antenna according to claim 1, wherein the connection between said first and second conductive plates and said ground plane is "L-shaped."

7. The antenna according to claim 1, wherein said first conductive plate is rectangular with a length equal to $1/_4\lambda_1$ and a width less than λ_1, and

wherein said second conductive plate is rectangular with a length equal to $1/4\lambda_2$ and width less than λ_2.

8. The antenna according to claim 1, wherein said first frequency is used for reception, and wherein said second frequency is used for transmission.

9. The antenna according to claim 1, wherein said first and second conductive plates are metal, said metal selected from a group of aluminum, copper, silver, brass, and gold.

10. The antenna according to claim 1, further comprising a plurality of additional conductive plates sized to resonate at different frequencies, each of said additional conductive plates separated from said ground plane by said dielectric medium and electrically connected to said ground plane;

and wherein said electrical connection electrically connects all of said conductive plates.

11. The antenna according to claim 1, wherein said antenna conforms to a non-planar surface.

12. The antenna according to claim 11, wherein said non-planar surface comprises a cellular telephone housing.

13. A dual-frequency-band patch antenna, comprising:

a ground plane;

a first conductive plate sized to resonate at a first frequency and separated from said ground plane by a first dielectric medium of a first thickness, said first conductive plate electrically connected to said ground plane;

a second conductive plate sized to resonate at a second frequency different from said first frequency and separated from said ground plane by a second dielectric medium of a second thickness, said second conductive plate electrically connected to said ground plane;

an electrical connection electrically connecting said first conductive plate to said second conductive plate; and

wherein said second thickness is sufficiently small such that when said first conductive plate resonates at said first frequency said second conductive plate draws a negligible current, and wherein said first thickness is sufficiently small such that when said second conductive plate resonates at said second frequency said first conductive plate draws a negligible current.

14. The antenna according to claim 13, wherein said first and second conductive plates transmit energy with a substantially omnidirectional beam pattern.

15. The antenna according to claim 13, further comprising:
a feed connected to said electrical connection; and
a signal unit connected to said feed.

16. The antenna according to claim 15, wherein said signal unit comprises an RF signal source, an RF signal receiver, or an RF transceiver.

17. The antenna according to claim 13, wherein said first and second dielectric medium are air.

18. The antenna according to claim 13, wherein the connection between said first and second conductive plates and said ground plane is "L-shaped."

19. The antenna according to claim 13, wherein said first conductive plate is rectangular with a length equal to $1/4\lambda_1$ and a width less than λ_1, and wherein said second conductive patch is rectangular with a length equal to $1/4\lambda_2$ and a width less than λ_2.

20. The antenna according to claim 13, wherein said first frequency is used for reception, and wherein said second frequency is used for transmission.

21. The antenna according to claim 13, wherein said first and second conductive plates are metal, said metal selected from a group of aluminum, copper, silver, brass, and gold.

22. The antenna according to claim 13, wherein said antenna conforms to a non-planar surface.

23. The antenna according to claim 22, wherein said non-planar surface comprises a cellular telephone housing.

24. The antenna according to claim 13, further comprising a plurality of additional conductive plates sized to resonate at different frequencies, each of said additional conductive plates separated from said ground plane by a dielectric medium and electrically connected to said ground plane; and wherein said electrical connection electrically connects all of said conductive plates.

25. A communication transceiver system, comprising:

a dual-frequency-band patch antenna, including:

a first conductive plate sized to resonate at a first frequency,

a second conductive plate sized to resonate at a second frequency different from said first frequency,

an electrical connection electrically connecting said first conductive plate to said second conductive plate,

a feed connected to said electrical connection, and

a ground plane separated from said first and second conductive plates by a dielectric medium of a certain thickness, said ground plane electrically connected to said first and second conductive plates, and wherein said thickness is sufficiently small such that when said first conductive plate resonates at said first frequency said second conductive plate draws a negligible current, and such that when said second conductive plate resonates at said second frequency said first conductive plate draws a negligible current; and

a signal unit connected to said feed.

26. The system according to claim 25, wherein said first and second conductive plates transmit energy with a substantially omnidirectional beam pattern.

27. The system according to claim 25, wherein said dielectric medium is air.

28. The system according to claim 25, wherein the connection between said first and second conductive plates and said ground plane is "L-shaped."

29. The system according to claim 25, wherein said first conductive plate is rectangular with a length equal to $1/4\lambda_1$ and width a width less than λ_1, and wherein said second conductive plate is rectangular with a length equal to $1/4\lambda_2$ and a width less than λ_2.

30. The system according to claim 25, wherein said first frequency is used for reception, and wherein said second frequency is used for transmission.

31. The system according to claim 25, wherein said first and second conductive plates are metal, said metal selected from a group of aluminum, copper, silver, brass, and gold.

32. The system according to claim 25, wherein said dual-frequency-band patch antenna further includes a plurality of additional conductive plates sized to resonate at different frequencies, each of said additional conductive plates separated from said ground plane by said dielectric medium and electrically connected to said ground plane;

and wherein said electrical connection electrically connects to all of said conductive plates.

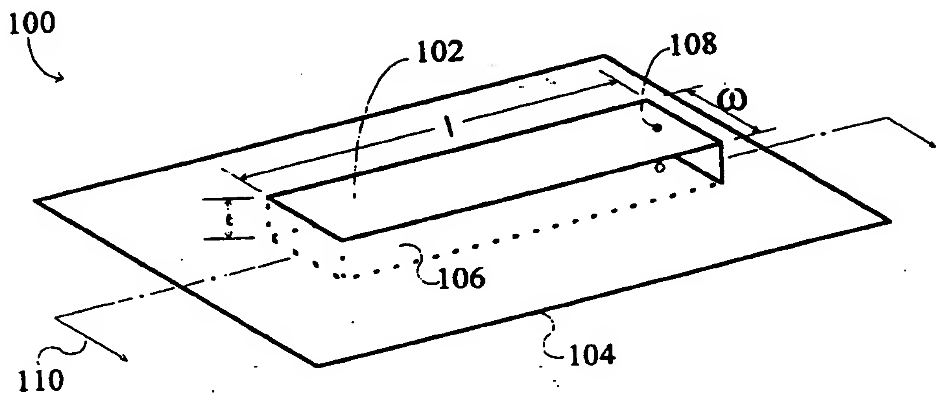

FIG. 1A

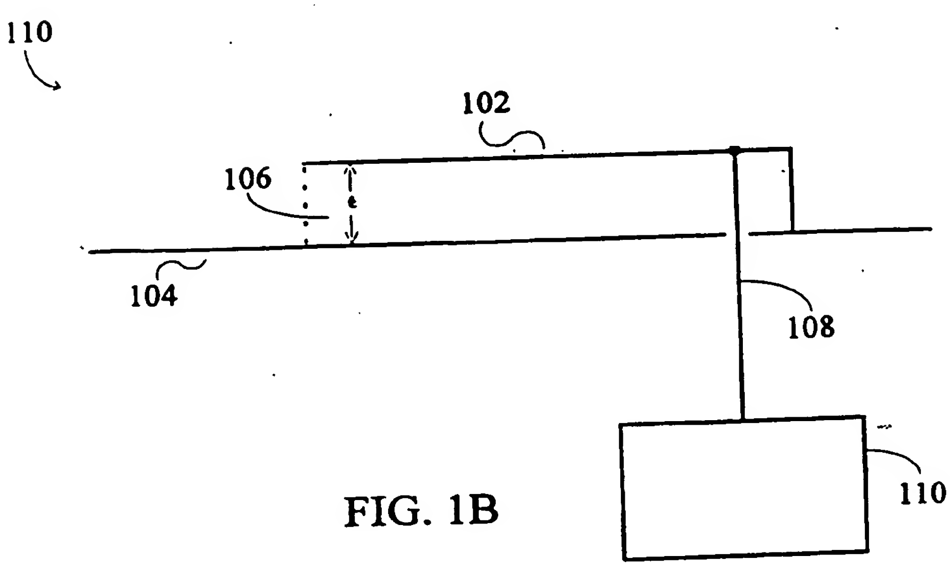

FIG. 1B

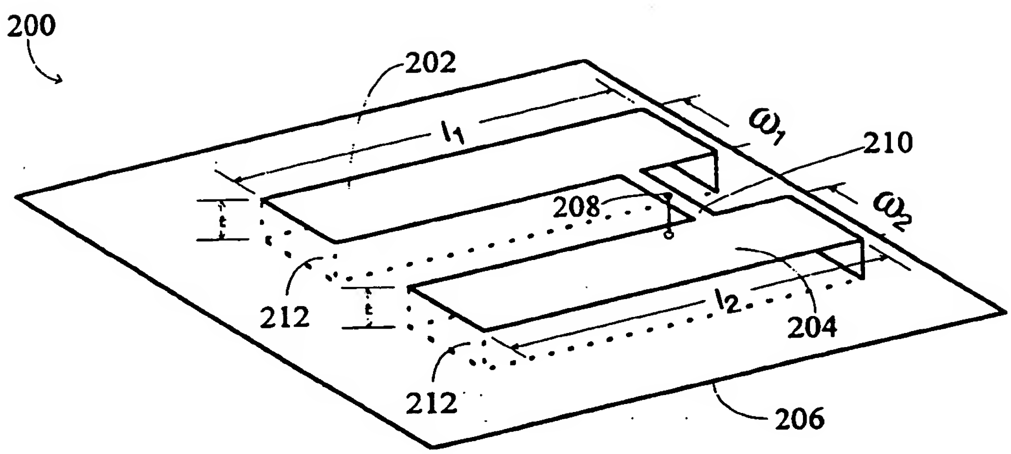

FIG. 2

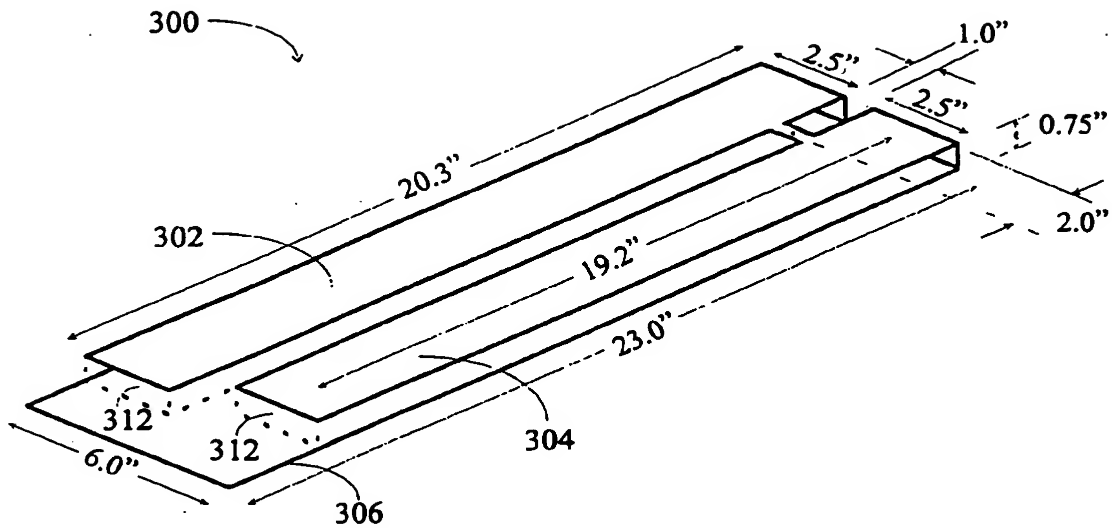

FIG. 3

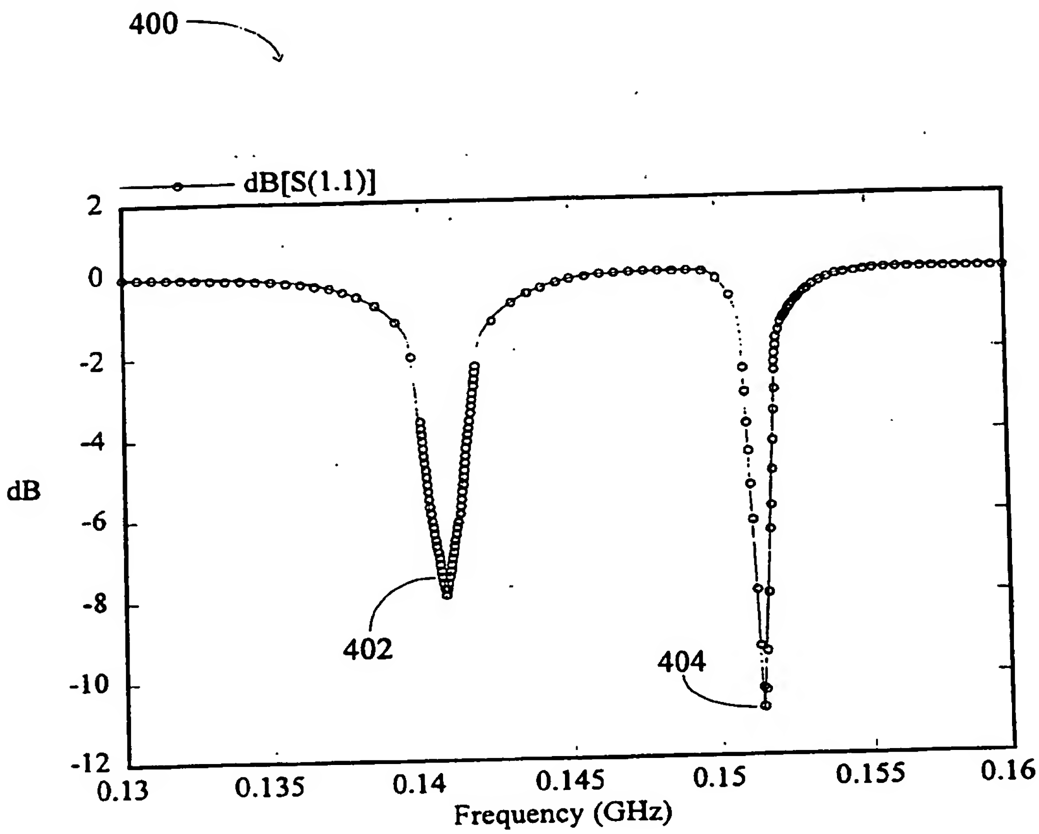
400
dB[S(1.1)]
2
0
-2
-4
-6
-8
-10
-12
dB
402
404
0.13
0.135
0.14
0.145
0.15
0.155
0.16
Frequency (GHz)

FIG. 4

500

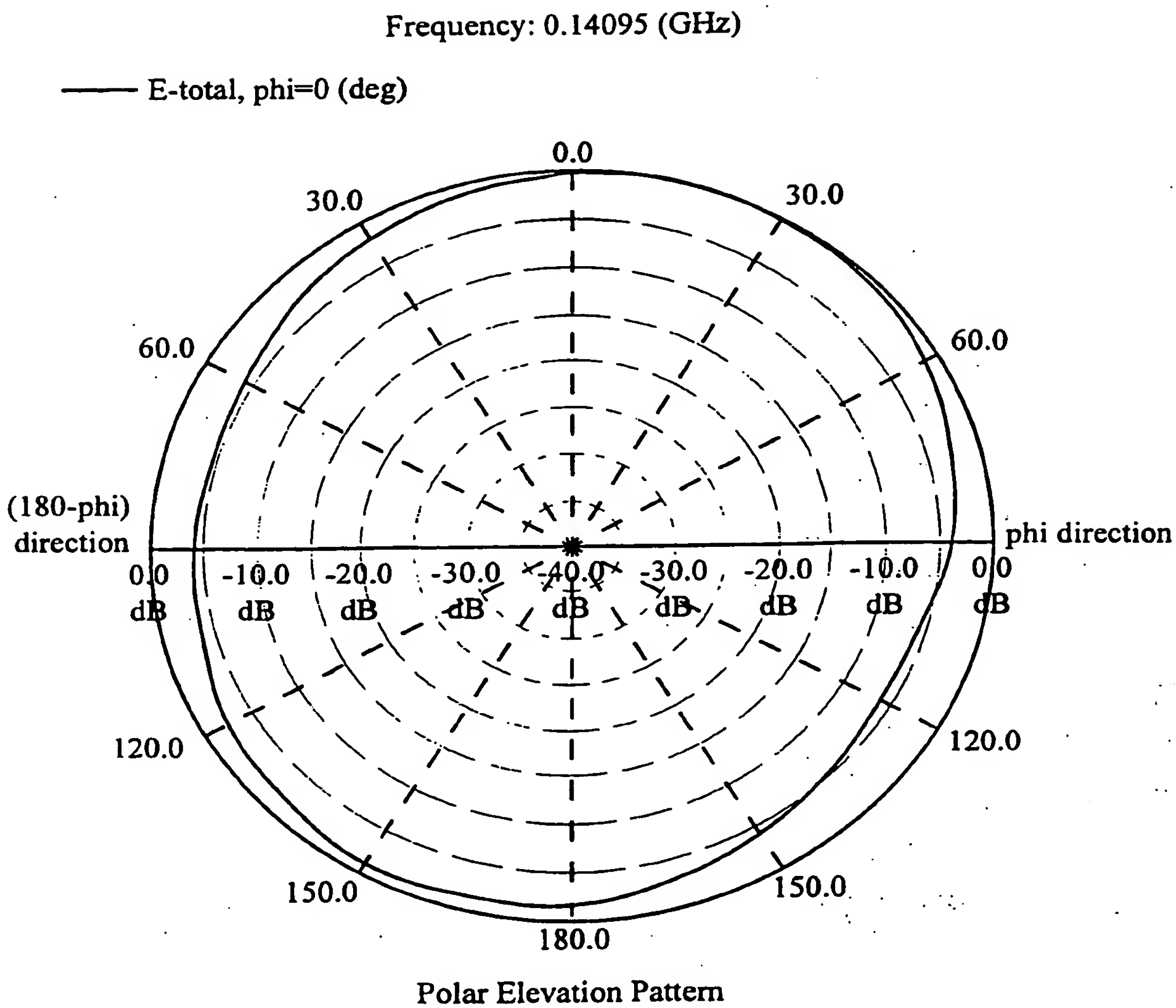
Frequency: 0.14095 (GHz)
E-total, phi=0 (deg)
0.0
30.0
30.0
60.0
60.0
(180-phi) direction
phi direction
0.0 dB
-10.0 dB
-20.0 dB
-30.0 dB
-40.0 dB
-30.0 dB
-20.0 dB
-10.0 dB
0.0 dB
120.0
120.0
150.0
150.0
180.0
Polar Elevation Pattern

FIG. 5A

502

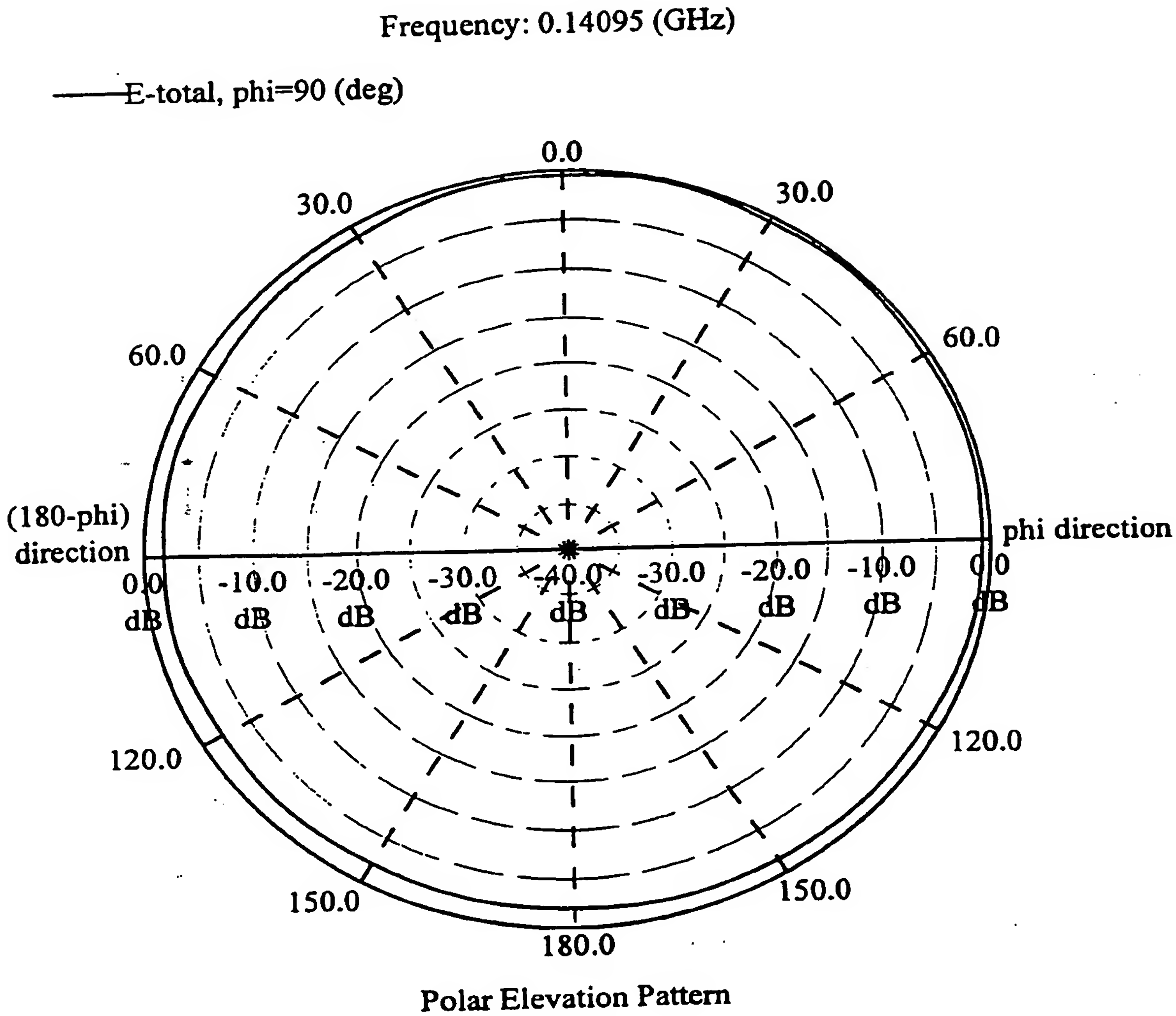
Frequency: 0.14095 (GHz)
E-total, phi=90 (deg)
0.0
30.0
30.0
60.0
60.0
(180-phi) direction
phi direction
0.0 dB
-10.0 dB
-20.0 dB
-30.0 dB
-40.0 dB
-30.0 dB
-20.0 dB
-10.0 dB
0.0 dB
120.0
120.0
150.0
150.0
180.0
Polar Elevation Pattern

FIG. 5B

600

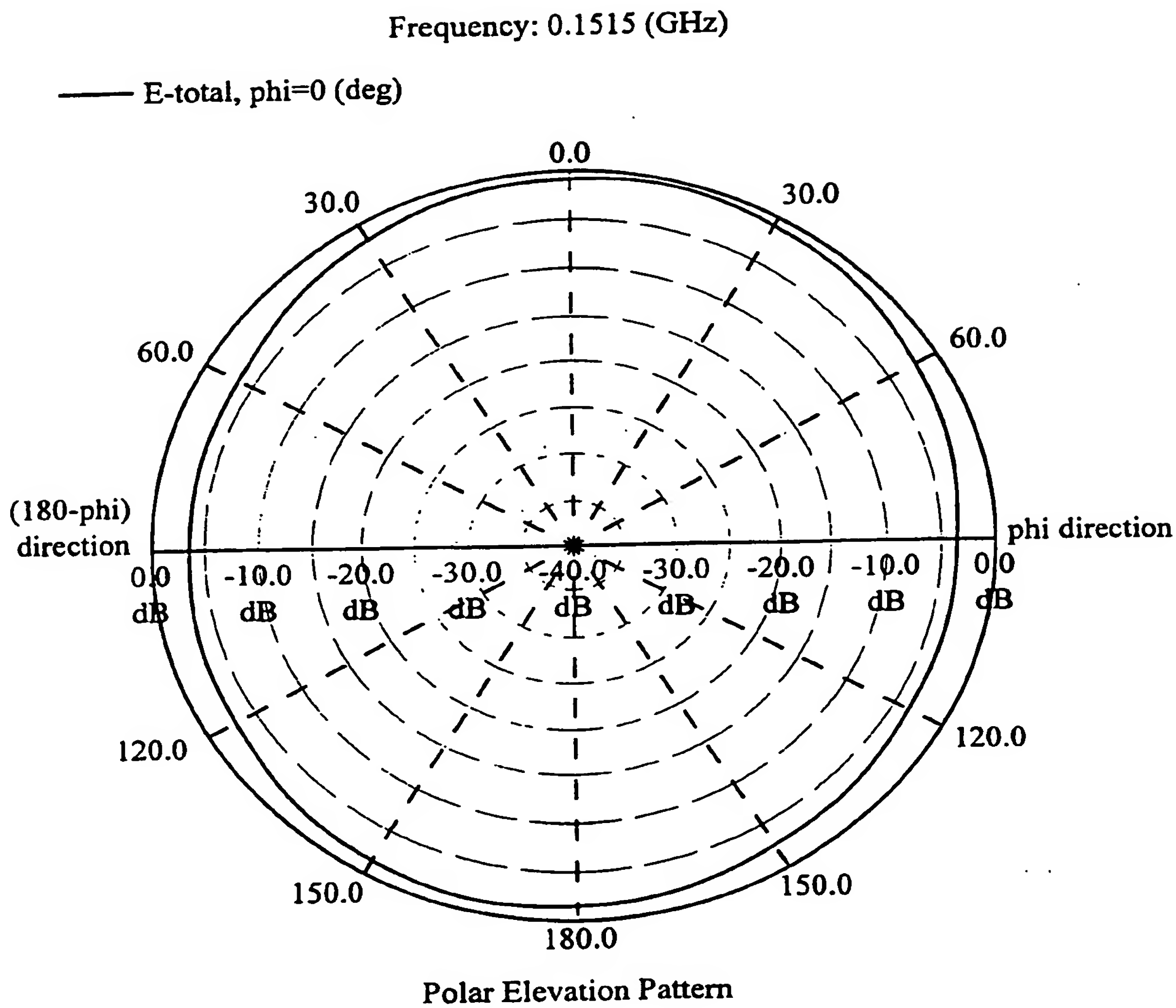
Frequency: 0.1515 (GHz)
E-total, phi=0 (deg)
0.0
30.0
30.0
60.0
60.0
(180-phi) direction
phi direction
0.0 dB
-10.0 dB
-20.0 dB
-30.0 dB
-40.0 dB
-30.0 dB
-20.0 dB
-10.0 dB
0.0 dB
120.0
120.0
150.0
150.0
180.0
Polar Elevation Pattern

FIG. 6A

602

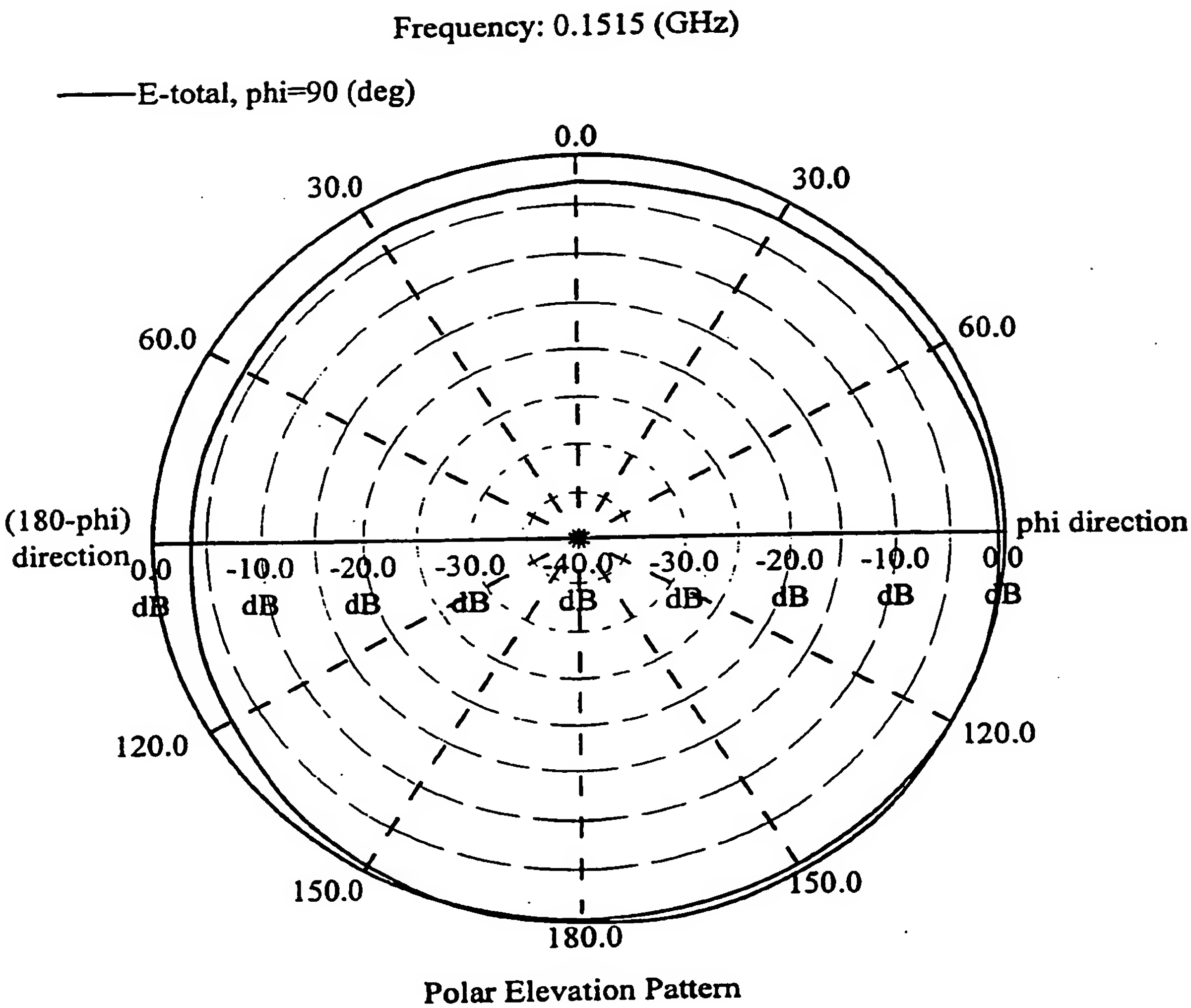
Frequency: 0.1515 (GHz)
E-total, phi=90 (deg)
0.0
30.0
30.0
60.0
60.0
(180-phi) direction
phi direction
0.0 dB
-10.0 dB
-20.0 dB
-30.0 dB
-40.0 dB
-30.0 dB
-20.0 dB
-10.0 dB
0.0 dB
120.0
120.0
150.0
150.0
180.0
Polar Elevation Pattern

FIG. 6B

INTERNATIONAL SEARCH REPORT

International Application No
PCT/US 98/05872

A. CLASSIFICATION OF SUBJECT MATTER
IPC 6 H01Q9/04 H01Q1/24

According to International Patent Classification(IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 6 H01Q

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
P,Y	US 5 644 319 A (CHEN ET AL.) 1 July 1997 see abstract; figures 2,3 see column 4, line 25 - line 38 ---	1,25
Y	US 5 365 246 A (RASINGER ET AL.) 15 November 1994 see abstract; figures 1,3 ---	1,25
P,Y	EP 0 777 295 A (NTT MOBILE COMMUNICATIONS NETWORK INC.) 4 June 1997 see figures 2,13 see column 4, line 35 - line 49 see column 8, line 21 - line 53 ---	13
Y	WO 91 01577 A (MOTOROLA,INC.) 7 February 1991 see abstract; figure 2 see page 3, line 19 - line 26 --- -/--	13

[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

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"O" document referring to an oral disclosure, use, exhibition or other means

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"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

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Date of the actual completion of the international search	Date of mailing of the international search report
4 June 1998	12/06/1998

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016	Danielidis, S

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C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
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Information on patent family members

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PCT/US 98/05872

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